Laser Beam Propagation in a Maritime Environment

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Abstract

The environmental impact on laser beam spreading is key in understanding how the intensity of laser light on target will change in different conditions. This report details the laser beam divergence of two beams: expanded (diameter 1 cm) and not expanded (dimeter 1 mm), over 380 m link. Laser beam dimeter spreading was measured at various distances to the target. Results demonstrate a larger increase in beam divergence from a non expanded beam.

Background

The United States Navy has been experimenting with seaborne laser weapons as a new means of defense against rising threats. The intent is to provide the Navy with an inexpensive but effective means of countering missiles, drones, and other airborne threats. Atmospheric conditions in the maritime environment pose a great challenge to the developing laser based weapons. Spreading, scattering, and attenuation are among factors that limit the effectiveness of a laser beam. A mitigation method of laser light intensity deterioration is to increase the beam radius at the source, resulting in preserving focused beam over a distance.

Experimental Setup

Equipment

Laser Source

- Survey-grade tripod
- Metal Breadboard with Threaded Holes
- Melles Griot 25-LHP-213-249 Serial NO: 4324FN-1 1mW Maximum @ 632.8nm
- Mounts Required to fix lasers and expander onto Breadboard
- Power Sources for the Lasers
- EL-25-20X-A - 20X Optical Beam Expander, AR Coated: 400 - 650 nm
- Gas Powered Generator

Camera

- 340M-GE - Fast Frame Rate VGA Monochrome Scientific Camera with Standard CCD Sensor, GigE, Navitar TV Zoom 7000 Optical Lens
- Power cord for camera
- Data cable for Camera
- Camera Compatible Laptop
- Adata Hard drive
- Portable Battery

Additional Supplies

- Laptop for Image Analysis
- Power Cable for the Laptop
- Nikon Laser Rangefinder
- Headlamps
- Presentation Board with Grid Lines

Aerial view of Sherman Field at the United States Naval Academy. Data collection locations are marked as follows: 1m, 11.5m, 49m, 122.5m, 237.5m, and 380m.

Hourly Weather History & Observations for 05 October 2017

Time (EDT)	Temperature (°F)	Dew Point (°F)	Humidity	Pressure (in)	Visibility (mi)	Wind Direction	Wind Speed	Conditions
7:54 PM	73.9	68.0	82%	30.12	10.0	Calm	Calm	Clear
8:54 PM	72.0	66.9	84%	30.12	10.0	Calm	Calm	Clear
9:54 PM	72.0	68.0	87%	30.12	10.0	Calm	Calm	Clear
10:54 PM	72.0	66.9	84%	30.13	10.0	Calm	Calm	Clear

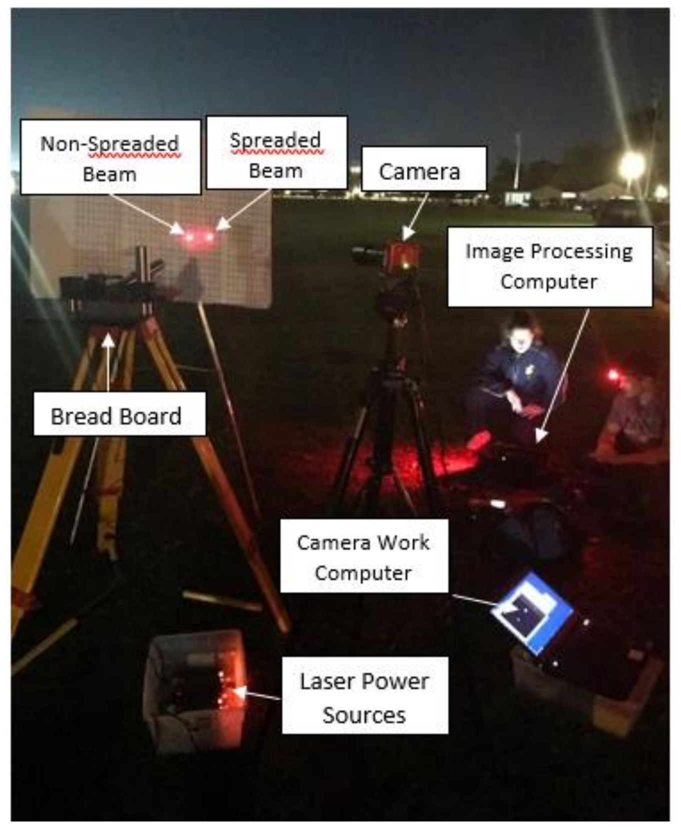
Methods

Prior to going out into the field the optics breadboard was setup with the lasers (with expanded and non expanded beam size) and the expander mounted.

The initial camera settings were calibrated in complete darkness as follows:

- Exposure time of 50 milliseconds
- Light aperture of 4.2

The complete outdoor experimental setup is given

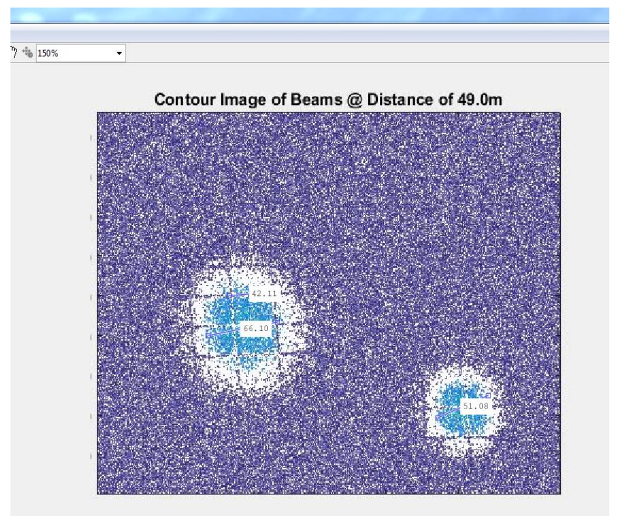


Data Collection Procedure

- Target boards placed down range from lasers
- Distance of boards recorded with Laser Range Finder
- Lasers adjusted to boards
- Camera positioned so both beams captured in one photo (~ 2m away), Headlamp used to illuminate grid paper
- Camera's lens focused so grid lines captured clearly; snapshot taken. Photo used to focus camera's lens for clear shot of lasers in the dark and serve as reference image for generation of the pixel ratio
- Headlamp turned off; camera auto scaled for snapshot of the beams
- Images transferred to MATLAB for immediate analysis of image saturation, if saturated another photo captured with reduced exposure time
- Power meter used to measure power per unit area of each beam
- The trajectory of the beams was lowered prior to moving to each distance for ease of placing them on the boards

Data Analysis Procedure

- In MATLAB 'imtool' command used to measure pixels of each beam's diameter (inner circle) and the pixel count of the known grid square's dimensions as shown in figure below
- Conversion factor created from known size of each reference grid
- Product of the spot's radius in pixels and the conversion factor resulted in the radius values measured in meters
- Images were normalized by determining the maximum value of each beam, the total image value was divided by the found maximum
- Through trial and error a scaling factor was found for which each image value was than multiplied by



'Imtool' command in MATLAB used to analyze and measure the pixels within the image

Results

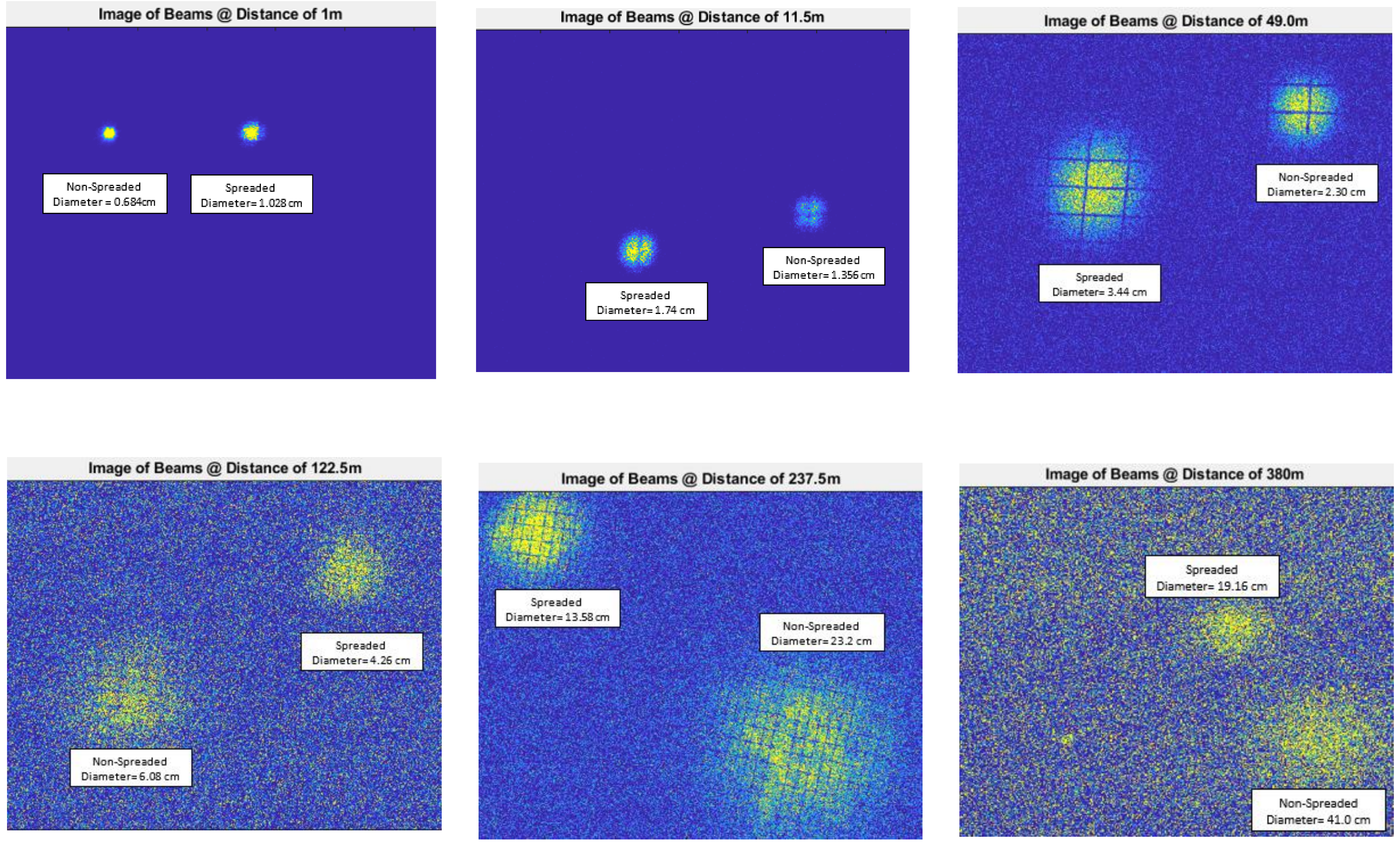
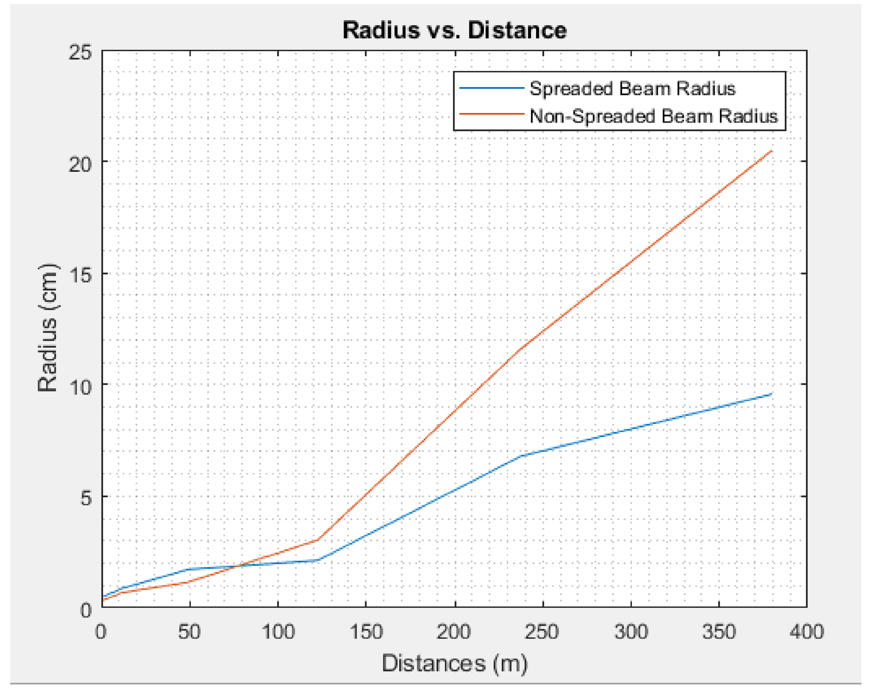


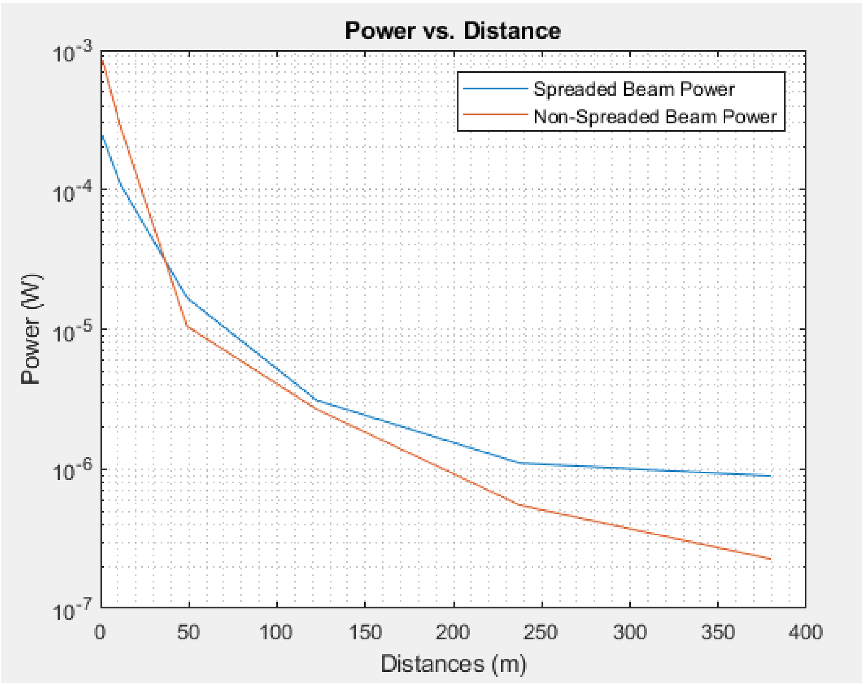
Image and 3-D Shaded Surface Plot of Beams for each distance.

Tabulated results of Power and Radius of Laser Beams

Distance (m)	Power (Spreader)	Power (No spreader)	Spreaded Radius (pixels)	Non-Spreaded Radius (pixels)	2 cm (pixels)	Conversion Factor (cm/pix)	Spreaded Radius (cm)	Non-Spreaded Radius (cm)
1	.244 mW	.855 mW	8.26	5.5	32.14	0.0622	0.514	0.342
11.5	107.8 μW	277.4 μW	13.5	10.51	31.02	0.0645	0.870	0.678
49	16.8 μW	10.5 μW	33.64	22.59	39.12	0.0511	1.72	1.15
122.5	3.1 μW	2.67 μW	20.36	29.04	19.1	0.105	2.13	3.04
237.5	1.1 μW	.55 μW	37.52	64.03	11.05	0.181	6.79	11.6
380	0.89 μW	226.2 nW	19.17	40.96	4	0.5	9.58	20.5



Plot comparing the radius size (cm) of the Spreaded and Non-Spreaded Beam at varying distances



Plot comparing the Power (W) of the Spreaded and Non-Spreaded Beam at varying distances using logarithmic scale.

Acknowledgements